

# Complete Description of the Erasmus Mundus Master Course - Modules description

## 1 Detailed Description of the Master Course

### 1.1 Objectives and how the Course contributes towards University excellence and European competitiveness

The objective of this new Joint European Master in Space Science and Technology is to combine the great diversity of space expertise at six European universities to a common platform of competence within the guidelines of the Bologna process. European and Third-country good quality students will in the framework of SpaceMaster have the possibility to study space science at excellent universities in Europe in a research oriented environment. Another objective is to give the students cross-disciplinary extension from laboratory and computer simulation environment to concrete situations such as balloon, rocket, satellite and radar control, tele robotics, sensor data fusion, automatic control and multi-body dynamics.

SpaceMaster will bring together as a core group students from the whole world to share the existing space competence, to develop it together and distribute it to benefit the European space industry and research community.

### 1.2 Masters Course Structure

**Table 1 and Table 2** give the structure of the SpaceMaster. An estimated number of around 95 Master's students (70 European + 25 from Third countries including 13 potential students from Asia) are planned to start at JMUW mid October 2005 with a preliminary START-UP week in Würzburg in late September. This event will be attended by staff from Partner Universities

The students will be enrolled (registered) at their home universities, apart from Third country students who will be enrolled in the Masters Consortium, coordinated by Luleå University of Technology. These are numbers for the year 2005-2006. Possibly there will be an increase in the amount of third country students for the following years.

| University             | CU | CTU | HUT | JMUW | LTU | UPS | Total |
|------------------------|----|-----|-----|------|-----|-----|-------|
| EU students            | 5  | 10  | 10  | 10   | 30  | 5   | 70    |
| Third country students | 2  | 2   | 2   | 2    | 3   | 2   | 13    |
| Asian widow students   | 2  | 2   | 2   | 3    | 2   | 2   | 13    |
| Total                  | 9  | 14  | 14  | 15   | 35  | 9   | 95    |

Table 1. Student distribution

|                   |   |                      |                      |                      |                      |                      |
|-------------------|---|----------------------|----------------------|----------------------|----------------------|----------------------|
| <b>Semester 1</b> | All students at JMUW taking core modules and optional modules in languages and Bavarian culture.            |                      |                      |                      |                      |                      |
| <b>Semester 2</b> | All students at LTU, Kiruna Campus, taking core modules and optional modules in languages and Sámi culture. |                      |                      |                      |                      |                      |
| <b>Semester 3</b> | CU<br>Track E1  | CTU<br>Track E5      | HUT<br>Track E2      | JMUW<br>Track E3     | LTU<br>Tracks E4, S3 | UPS<br>Tracks S1, S2 |
|                   | 5 CU  | 10 CTU               | 10 HUT               | 5 JMUW               | 13 LTU               | 5 UPS                |
|                   | 3 3 <sup>rd</sup> C.  | 3 3 <sup>rd</sup> C. | 3 3 <sup>rd</sup> C. | 3 3 <sup>rd</sup> C. | 4 3 <sup>rd</sup> C. | 3 3 <sup>rd</sup> C. |
|                   | 2-3 LTU   | 2 LTU                | 2-4 LTU              | 2-4 LTU              |                      | 4-6 LTU              |
|                   | 1JMUW   | 2JMUW                | 2 JMUW               |                      |                      |                      |
|                   | 3 Asia  | 3 Asia               | 3 Asia               | 3 Asia               | 3 Asia               | 3 Asia               |
| Total 15          | Total 20  | Total 22             | Total 14             | Total 20             | Total 16             |                      |
| <b>Semester 4</b> | Work on the Master Thesis. Supervisors from two Institutions.   |                      |                      |                      |                      |                      |

**Table 2. SpaceMaster structure and approximate numbers of students at each Track**

### 1.2.1 First Semester, Core Modules, 30 ECTS, at JMUW, Germany

The modules to be taken by all students will be:

1. Introduction in Space Physics (7.5 ECTS)
2. Spacecraft System Design (7.5 ECTS)
3. Space dynamics (7.5 ECTS)
4. Programming, Embedded Control, Communication (7.5 ECTS)

(Each module is structured as 4 hours per week, equivalent to 7.5 ECTS credits, giving a total of 30 ECTS).

These studies are complemented by language tuition, as described in section 2.17, Events to experience Bavarian culture will be organised.

Module Descriptions

#### 1.2.1.1 Introduction in Space Physics (7.5 ECTS), Prof. Karl Mannheim + collaborators

- Basics of plasma physics: Single particle motion, trapped particles, kinetic theory, magneto hydrodynamics, plasma waves.
- Geophysical plasma: Earth's atmosphere and magnetic field, ionosphere, convection and current systems, radiation belts.
- Interplanetary plasma: Solar wind, solar activity, shock waves, particle acceleration.
- Small bodies in the solar system.
- Radiation damage.
- Space weather.

#### 1.2.1.2 Spacecraft System Design (7.5 ECTS), Prof. Klaus Schilling + collaborators

The aim is to provide understanding of the requirements for spacecraft design, the basic components of a spacecraft system and the design procedure for such systems. After completion a student should know about:

- Mission analysis, characterisation and evaluation.
- Typical components of a ground and a space system.
- Subsystems, composing a spacecraft, and their characteristic parameters.
- Common techniques and requirements occurring in space missions.
- Characteristics of telecommunication, space exploration and Earth observation missions.
- System budgets, link, mass, and power.

#### 1.2.1.3 Space Dynamics (7.5 ECTS), Prof. Klaus Schilling + collaborators

To provide understanding of the basic principles of space dynamics and of their applications to typical mission analysis problems. On completion of this module a student should understand:

- Keplerian motion.
- Orbit perturbations and effects on orbit.
- Orbital manoeuvres.
- Attitude dynamics and kinematics.
- Determination of orbit properties, like telecommunication links, surface coverage and eclipses.
- Interplanetary orbits.

#### **1.2.1.4 Programming, Embedded Control, Communication (7.5 ECTS), Prof. Klaus Schilling + collaborators**

The aim is to introduce students to software and hardware systems of relevance for spacecraft operations. An overview on the main approaches in programming, control engineering and telecommunication will be presented. After the end of this lecture the students should:

- Have the background on computer system design.
- Be able to program in common computer languages.
- Understand basics of micro processors and embedded systems design.
- Be familiar with sensor data acquisition and processing schemes.
- Know about protocols and signal processing in a radio link, modulation and coding.

### **1.2.2 Second Semester, Core modules, 30 ECTS at LTU, Sweden**

The modules to be taken by all students will be:

1. Spacecraft Environment Interaction (7.5 ECTS).
2. Electronics in Space (7.5 ECTS).
3. Image Processing and Remote Sensing (7.5 ECTS)
4. Optics- and Radar-based Observations (7.5 ECTS)

Complementary language tuition as outlined in section 2.17 will be available. In addition, events to experience the Sámi culture will be arranged.

#### Module Descriptions

##### **1.2.2.1 Spacecraft Environment Interactions (7.5 ECTS), Dr. Johnny Ejemalm**

In the course you learn about the environment that the spacecraft encounter, and also about how that environment interacts with the spacecraft with its instruments. You also learn about the methods that are used to overcome harmful effects on the spacecraft by its environment. The spacecraft, often a satellite, is in vacuum, leading to outgassing of particles from the spacecraft resulting in a risk of contamination of sensitive surfaces. The spacecraft is in an extreme thermal environment, with cold space and warm sunshine, to which it must adapt itself. It is also exposed to other types of high energetic radiation of corpuscular or continuous form, which can affect solar panels and electronics. The spacecraft also has a risk of colliding with micrometeoroids and orbital debris. In lower orbits there is a risk of collision with different molecules, which can induce chemical reactions on the surface of the spacecraft or simply slow the spacecrafts velocity down. The spacecraft has also a risk of being electrically charged by the plasma that is in the space, with a following risk of sudden electrostatic discharge or affection on instruments.

##### **1.2.2.2 Electronics in Space (7.5 ECTS), Director of Studies Alf Wikström+ collaborators**

The course aim is to give the student an understanding of the hazards and problems that electronic circuits and components face in space and how these hazards and problems may be overcome. Also space radiation, design of semiconductor devices, materials, total dose, ionisation, EMC and testing techniques in space will be covered in the course.

##### **1.2.2.3 Image Processing and Remote Sensing (7.5 ECTS), MSc Anita Enmark**

The aim of the course is to give an understanding of basic concepts and techniques in remote sensing and digital image processing for space applications. Basic concepts: Electromagnetic spectra, spectral signatures, satellites,

sensors, geometric and radiometric resolution, interactions in the atmosphere. Pre processing: System correction, radiometric correction, geometric correction, deconvolution. Image enhancement: Contrast manipulation, filtering, colour composites, principal analysis etc. Digital classification. Space applications (aurora images, astronomy, environmental monitoring from space). File formats. Image compression and coding.

#### **1.2.2.4 Optics- and Radar-based Observations (7.5 ECTS), Associate Professor Asta Pellinen-Wannberg,**

The aim of the course is to give understanding of the principles for ground based systems making observations in the Earth's atmosphere and ionosphere. One of the receiver stations of the European Incoherent Scatter (EISCAT) radar is located in Kiruna. The students will get a chance to run the radar and analyse the data. Even other instruments in Kiruna are presented such as the optical network ALIS, the ESRAD radar and the IRF lidar. Course content: Radiometry, fundamentals of absolute optical measurements, photometers, low-light spectroscopic imaging systems, spectrometers, interferometers, lidars, mm-wave techniques, and radiometers. Types of radars and applications: power and range equations. pulsed radars, doppler pulsing, CW-radar, tracking and scanning radars, antennas, SAR-radar and incoherent scatter radar with applications.

The 30+30 ECTS that the students have earned at JMUW and Kiruna will be recognised by all partner universities there will be a global agreement between the Partner Universities that regulates this. Such an agreement is in course of preparation at the time of this proposal.

### **1.2.3 Third Semester**

During the Third Semester there are optional Tracks at different universities. The students will earn 30 ECTS at each institution. There may be some students that spend the 3rd Semester at TWO institutions. The 30 ECTS is recognised by all universities.

The different tracks during the Third Semester are:

**E1 Engineering Track 1**

**E2 Engineering Track 2**

**E3 Engineering Track 3**

**E4 Engineering Track 4**

**E5 Engineering Track 5**

**S1 Scientific Track 1**

**S2 Scientific Track 2**

**S3 Scientific Track 3**

#### **1.2.3.1 Engineering Track 1, 30 ECTS, at CU, UK, – Dynamics and Control of Systems and Structures**

The modules will be:

1. Space Propulsion (5.0 ECTS).
2. Introduction to Space Structures (2.5 ECTS).
3. Statics of Structures, Dynamics of Structures (5.0 ECTS).
4. Fiber Reinforced Plastics (5.0 ECTS).
5. Rigid Spacecraft Dynamics (5.0 ECTS).
6. Classical Control Methods (5.0 ECTS).
7. Multivariable Control for Aerospace Applications (5.0 ECTS).
8. GPS and INS (5.0 ECTS).
9. Group Design Project (30 ECTS).

Module Descriptions

##### **1.2.3.1.1 Space Propulsion (5.0 ECTS), Professor J. B. Moss**

The aim is to provide an understanding of the thermo fluid dynamic concepts underlying rocket and air-breathing space propulsion and of their implications for launch vehicle and spacecraft system performance and design. On completion of this module the student should:

- Understand the constraints imposed by launch vehicle performance & operation on mission analysis.
- Be able to perform preliminary mission design studies which accommodate the capabilities of the major launch systems currently available.
- Be able to use one-dimensional gas dynamic relationships to perform initial propulsion system design point and off-design calculations.
- Be familiar with the principal options for propulsion system design in relation to both boosters and secondary spacecraft propulsion, and to be able to assess critically their relative strengths in a range of mission applications.
- Understand the determining factors in high speed flows which constrain the application of air-breathing propulsion to space launcher applications and the current responses to the technical challenges posed.

#### **1.2.3.1.2 Introduction to Space Structures (2.5 ECTS), Prof. R. Vignjevic, J. Brown**

The aim is to provide an introduction to structural design, particularly for spacecraft, for students with little previous experience of structural engineering. On completion of this module the student should:

- Understand the role of the spacecraft structure and its typical operating environment.
- Be familiar with the response of materials and structures to applied loads.
- Understand the role of different structural components.
- Appreciate the significant features of the dynamic response of a structure.

#### **1.2.3.1.3 Statics of Structures, Dynamics of Structures (5.0 ECTS), J. Brown, Prof. R. Vignjevic**

The aim is to introduce structural analysis techniques for both static and dynamic cases. At the end of this module students should:

- Understand and be able to apply basic structural analysis methods.
- Have a qualitative understanding of the dynamic response of structures.
- Understand and be able to apply more advanced structural analysis methods.
- Understand quantitative methods for analysing structural dynamics.

#### **1.2.3.1.4 Fiber Reinforced Plastics (5.0 ECTS), Dr. S. Guo**

The aim is to introduce composite materials for aerospace applications and to describe design methods, analytical tools and test methods relevant to their use. On completion of this module the student should be able to apply his/her knowledge to the practical design aspects of composites for aerospace structures, in particular:

- Understand the key features of composite materials for aerospace use.
- Be aware of particular properties and design tools and practices for composite materials, especially fibre reinforced plastics.
- Be aware of analytical techniques for moisture and thermal effects.
- Be aware of the buckling behaviour of composites.
- Be familiar with design techniques for composite materials.
- Be aware of test methods for fibre reinforced plastics.

#### **1.2.3.1.5 Rigid Spacecraft Dynamics (5.0 ECTS), Prof. R. Vignjevic**

The aim is to provide an introduction to the rigid body dynamics of spacecraft. At the end of this module students should understand and be able to apply:

- Concepts of the kinematics of rotational motion.
- Aspects of rigid body dynamics to spacecraft.

### **1.2.3.1.6 Classical Control Methods (5.0 ECTS), Dr. J. F. Whidborne**

The aim is to provide understanding of some of the mathematical techniques and knowledge of the fundamentals of control engineering for the analysis and synthesis of control systems in aerospace applications. On completion of this module the student should:

- Use Laplace transform techniques to derive transfer functions of systems.
- Calculate and plot the step response and frequency response of systems.
- Derive matrix state equations for systems.
- Use MATLAB for matrix algebra and to plot system responses.
- Apply their understanding of control engineering techniques to a range of simple real-world engineering problems.
- Use modern PC-based CAD software as an aid in the solution of control engineering problems.

### **1.2.3.1.7 Multivariable Control for Aerospace Applications (5.0 ECTS), Dr. J. F. Whidborne**

The aim is to provide an introduction to modern robust multivariable control techniques for the analysis and design of aerospace control systems. On completion of this module the student should:

- Have an appreciation of the complexities of advanced control theory and the requirements of current aerospace control systems.
- Be able to apply a range of advanced design and analysis techniques to typical aerospace control problems.
- Be able to use PC-based tools such as MATLAB and its toolboxes in the application of these techniques to real-world aerospace control problems.

### **1.2.3.1.8 GPS and INS (5.0 ECTS), Dr. S. E. Hobbs**

The aim of this module is to provide an introduction to the principles of aerospace navigation systems based on inertial sensors and satellite navigation. On completion of the module the student should:

- Understand the roles of inertial and satellite navigation in aerospace.
- Understand inertial navigation principles, error sources, and aerospace applications.
- Understand satellite navigation principles, error sources, applications and key issues.

### **1.2.3.1.9 Group Design Project (30 ECTS), Supervisors: Tom Bowling, Dr. Stephen Hobbs, Dr. Peter Roberts, Dr. Jenny Kingston**

The group design project enables students to experience the application of their specialist skills to a collaborative interdisciplinary project and is a valuable learning experience. Subjects for the project are chosen to give students scope for developing their abilities and will usually be topical to current or anticipated interests of the space industry and may thus have direct relevance to the careers of graduates of the course.

The aims of the group design project are to provide students with experience of working on a collaborative space engineering project and to integrate the separate subjects taught in the lecture modules.

On completing the project, students should:

- Understand the organisation of team projects, and be familiar with project progress monitoring and reporting.
- Appreciate the role of specific sub-systems within an interdisciplinary project, including sub-system - sub-system and sub-system - system interactions.
- Understand the space system design process.
- Be able to apply their specialist skills effectively in an interdisciplinary collaborative project.
- Students taking Engineering Track 1 can accumulate up to a maximum of 30 ECTS credits by taking an approved selection of the above modules, assessed by written examination. In addition, additional optional modules to aid the research thesis work or group design project may be attended. These include computer software skills such as MatLab /Simulink, Satellite Tool Kit, CAD Modelling with I-DEAS or CATIA and Finite Element Methods using NASTRAN / PATRAN.

### **1.2.3.2 Engineering Track 2, 30 ECTS, at HUT, Finland – Space Robotics**

The modules will be:

1. Machine Perception (3 ECTS).
2. Positioning and Navigation Methods (3 ECTS)
3. Automation and Control Technology (4.5 ECTS)
4. Robotics (3 ECTS)
5. Field and Service Robotics (4.5 ECTS)
6. Behavior-based Robotics (3 ECTS)
7. Kinematics and Motion Planning (3 ECTS)
8. Bionics (3 ECTS)
9. Mechatronic Miniature Automation (3 ECTS)
10. Project in Automation Technology (3-9 ECTS)

Module Descriptions

#### **1.2.3.2.1 Machine Perception (3 ECTS), Professor Arto Visala**

Contents: Widens ability to do signal processing in automation. Particularly, perception processing methods in robots and autonomous machines. Dynamic machine vision, signal processing in connection with laser scanners and ultrasonic sensors. Overview of biological sensor-motor mechanisms.

#### **1.2.3.2.2 Positioning and Navigation Methods (3 ECTS), Jorma Selkänaho, Lic.Sc. (Tech.), Pekka Forsman, D.Sc. (Tech.)**

Contents: Methods of positioning of mobile objects. Dead reckoning. Methods based on fixed beacons. Feature based positioning. Simultaneous mapping and positioning. Generic RF-methods, GPS, utilisation of wireless mobile communication networks. Estimation methods of focusing position. Literature: Lecture notes.

#### **1.2.3.2.3 Automation and Control Technology (4.5 ECTS), Professor Aarne Halme**

Contents: Automation in factories, machines, vehicles, and in other machines and devices. Measurements and actuators in the controlled process/machine. Automation system architecture and functions, hardware and software. Binary and fuzzy logic control. Modeling of dynamic systems. Feedback control. Exercises and laboratory work.

#### **1.2.3.2.4 Robotics (3 ECTS), Pekka Forsman, D.Sc. (Tech.)**

Contents: Basics in robotics. Industrial robots, mobile robots and robot-like machines. Structure of robots (mechanisms, grippers, sensors, sensing and control systems). Basic kinematics and motion control principles. Examples of various practical applications of robotics.

#### **1.2.3.2.5 Field and Service Robotics (4.5 ECTS), Prof Aarne Halme, Jussi Suomela, Lic.Sc. (Tech.)**

Contents: Mobile intelligent machines and robots. Functional subsystems: motion and energy, piloting, sensor and perception, navigation, control and supervising, work task management system. Technical solutions of subsystems. Locomotion theory, particularly walking. Assignment work.

#### **1.2.3.2.6 Behavior-based Robotics (3 ECTS), Mika Vainio, D.Sc. (Tech.)**

Contents: Planning and use of behaviour-based robots. Generic design principles through study of existing robot systems. Overview of biological perception and learning, corresponding technical solutions. Control architectures. Distributed robot systems. New paradigms in robotics.

#### **1.2.3.2.7 Kinematics and Motion Planning (3 ECTS), Sami Ylönen, Lic.Sc. (Tech.)**

Contents: Advanced kinematic modelling. Introduction to robot dynamics. Modelling of mobile robots. Motion planning, collision free paths. Force control. Applications. Exercises.

#### **1.2.3.2.8 Bionics (3 ECTS), Lecturer: N.N.**

Contents: Utilization of principles and mechanisms developed from biological evolution in the planning of manufactured machines and their control. Areas covered include light and solid structures, energy conversion principles and systems, loco-motion systems, perception and navigation systems, simple and flexible reasoning and inference methods, swarm intelligence, superior adaptation mechanisms.

#### **1.2.3.2.9 Mechatronic Miniature Automation (3 ECTS), Pekka Appelqvist, D.Sc. (Tech.), Anja Ranta, M.Sc. (Tech.)**

Contents: Structure of mechatronic automation system. Electronic components. Micro-sensors and actuators, integration to mechanics. Development of embedded software. Application examples.

#### **1.2.3.2.10 Project in Automation Technology (3-9 ECTS), Ilkka Leppänen, M.Sc. (Tech.)**

Contents: Variable size guided "learning by doing" project which is done individually or usually in teams of 2-3 students. Students apply suitable methods to solve, implement, and test given tasks. The titles are given and guided by research and teaching staff. Titles are selected so that the projects can benefit from the results or teaching material can be developed. The schedule for the work is agreed in advance.

#### **1.2.3.3 Engineering Track 3, 30 ECTS, at JMUW, Germany – Automation, Control and Communication of Space Robotics**

The modules will be:

1. Robotics1+2 (12 ECTS)
2. Automation and Control (7.5 ECTS)
3. Computer and Communication Networks, (12 ECTS)
4. Telecommunication Networks in Space (3 ECTS)
5. Group Project (3-9 ECTS)

Module Descriptions

#### **1.2.3.3.1 Robotics1+2 (12 ECTS), Prof. Dr. Klaus Schilling**

Robots are playing a key role in Industry. An unmanned spacecraft can be also considered as a distant robot. Therefore this course conveys the student an overview over technical background of manipulators and mobile robots. The core topics are: direct and inverse kinematics and dynamics, sensors and actuators, path planning and control strategies. Furthermore system architecture, autonomy und adaptive control, remote control, supervisory control, user interfaces and methods of tele-presence will be discussed. Other important topics are mobile robots and planetary rovers.

#### **1.2.3.3.2 Automation and Control (7.5 ECTS), Prof. Dr. Klaus Schilling**

#### **1.2.3.3.3 Computer and Communication Networks, (12 ECTS), Prof. Dr.-Ing. Phuoc Tran-Gia**

The core topics are: features of computer and communication networks, architecture of computer networks, protocols, performance evaluation of computer networks, TCP/IP, routing in the Internet, switching systems, service integration, mobile communication systems, ATM and high-speed networks.

#### **1.2.3.3.4 Telecommunication Networks in Space (3 ECTS), Prof. Dr. Klaus Schilling**

Satellites are providing connections between heterogenic network segments in a satellite based internet system. Such a network allows the representing of satellites as services within the generic internet. The needed system architectures and technical background is the main content of this seminar. Further it will give an overview over the basic concepts and conveys the knowledge of distributed systems, radio links and ground stations to the involved students.

#### **1.2.3.3.5 Group Project (3-9 ECTS), Prof. Dr. Klaus Schilling and collaborators**

In this project the students are working on a complex task in teams of 2-3 students. The topics are selected in the scope of pico-satellites (satellite system design, mechanical and electrical subsystem layout, mission planning), ground station networks (telecommunication, tracking, ground control station data flow) and internet in space (efficient protocols noise effects on telecommunications). Beside the scientific work they will train their soft skills in cooperation and presentation techniques. Students apply suitable methods to solve, implement, and test given tasks. The schedule for the work and deadlines are agreed in advance.

#### **1.2.3.4 Engineering Track 4, 30 ECTS, LTU, Sweden – Space Technology and Instrumentation**

The modules will be:

1. Space Vehicle Systems (7.5 ECTS)
2. Principles for Space Instruments (7.5 ECTS)
3. Instrument design and measurement techniques for spectroscopic imaging (7.5 ECTS)
4. Balloon project BEXUS at Esrange (Could be part of the Thesis work)
5. The Rocket Project REXUS at Esrange (Could be part of the Thesis work)

Module descriptions

##### **1.2.3.4.1 Space Vehicle Systems (7.5 ECTS), Dr. Priya Fernando**

Description: The aim of the course is to give an overview of space vehicle systems related to launchers, satellite design and space project management. Topics covered are sounding rockets, launchers, propulsion, launch and spacecraft trajectory calculations. Students are given a rare opportunity to work on various space projects to get a first hand training in project management, system verification and testing. During the course the students work on a nano satellite group design project. The objective of the project is to build and test a nano satellite to meet the given design specifications. The satellite should build to such a standard to survive the drop test and the IRF thermal vacuum chamber test.

##### **1.2.3.4.2 Principles for Space Instruments (7.5 ECTS), Dr. Victoria Barabash**

Description: The course gives information of the state of the art of sensors and instruments used in observational and experimental space physics including physics principles, advantages, disadvantages and platform requirements. Also included is how space science projects are designed and selected. The major part of the course is devoted to instruments for in-situ measurements from satellites, sounding rockets and balloons, but ground-based measurement methods are also covered.

The teaching is a combination of lectures by a number of specialists and two group assignments. The first group assignment involves analysis of a satellite project proposal, the second one is to design a satellite instrument project and write and present a proposal. There is also one practical about computer simulation of a particle instrument.

##### **1.2.3.4.3 Instrument design and measurement techniques for spectroscopic imaging (7.5 ECTS), Dr. Urban Brändström**

Description: The course will give an introduction to instrument design and measurement techniques for spectroscopic imaging in observations of various optical phenomena in space physics such as aurora, artificial airglow and meteors. The contents of the course: Scientific requirements, why bother with all this?, imaging darkness, spectroscopic imaging, etc., Imaging detectors: (IPD), CCDs, image intensifiers, (CMOS sensors), filters, interference filters, (Fabry-Perot etalon), optical systems for spectroscopic imaging, instrument design, basic radiometry, SNR estimations, overview of image processing, absolute optical measurements, calibration techniques: (light standards, integrating spheres), actual spectroscopic imaging systems: ALIS, and others, planning and performing an observation with ALIS (Aurora/Meteors/RIOE (radio induced optical emissions)/calibration - if weather permits otherwise analyse old data), doing the initial data-analysis (image reductions)

##### **1.2.3.4.4 Balloon project BEXUS at Esrange, Alf Wikström**

Description: The Swedish Space Corporation (SSC) offers the students at the Space Campus a unique opportunity to design, build and fly their own experiments on stratospheric balloon platforms launched from Esrange. The launches are planned to occur annually in mid or late January (<http://www.krm.se/bexus/eng/>).

#### **1.2.3.4.5 Rocket Project REXUS at Esrange, Director of Studies Alf Wikström+ collaborators**

Description: The Swedish Space Corporation (SSC) and the German Aerospace Center (DLR) offer the students at the Space Campus a unique opportunity to design, build and fly their own experiments on sounding rockets launched from Esrange. The launch in 2004 will take place in October. (<http://rexus.krm.se/default.asp?sida=2>).

#### **1.2.3.5 Engineering Track 5, 30 ECTS, at CTU, Czech Republic –Space Automation and Control**

The modules will be:

1. Space Systems, Modeling and Identification (7.0 ECTS)
2. Optimal and Robust Control Design (7.0 ECTS)
3. Estimation, Filtering and Fault Detection (7.0 ECTS)
4. Real-time Software Components for Space Control (7.0 ECTS)
5. Distributed Embedded Systems (7.0 ECTS)
6. Hardware Support in Space Engineering (7.0 ECTS)
7. Team Design Project (10.0 ECTS)

Module Descriptions

##### **1.2.3.5.1 Space Systems, Modeling and Identification (7.0 ECTS), Prof. V. Kučera**

To provide an introduction to systems theory and properties, models building and identification methods. After completion of this module, the student should

- be familiar with various types of systems (continuous-time and discrete-time, linear and nonlinear, scalar and multivariable, uncertain, time-invariant, time-varying, etc.
- understand fundamental properties of space systems including stability, controllability observability and realizability
- create and use input-output and state-space models
- master model reduction and data sampling techniques
- apply various deterministic and stochastic identification procedures
- understand feedforward and feedback control structures
- use modern software tools for systems analysis, modeling and simulation (e.g. Matlab and its toolboxes)

##### **1.2.3.5.2 Optimal and Robust Control Design (7.0 ECTS), Prof. M. Šebek**

To introduce and train classical and modern optimal and robust control design methods, algorithms and tools. After completion of this module, the student should

- be able to design and tune LQ and LQG optimal controllers
- apply principles of time-optimal and finite impulse response systems
- be familiar with uncertain systems of various kind (parametric, interval, unstructured, etc.)
- analyze robustness of system stability and performance
- apply modern optimization techniques to design robust controllers (e.g. semidefinite programming)
- able to design H-2 and H-infinity optimal robust controllers

##### **1.2.3.5.3 Estimation, Filtering and Fault Detection (7.0 ECTS), Prof. V. Havlena**

To provide an introduction to problems of estimation, filtering and fault detection in space born systems. After completion of this module, the student should

- compute estimates of various types including mean squares, maximum likelihood and Bayesian
- understand and design Wiener and Kalman filtering
- apply deterministic and stochastic fault detection methods

- be familiar with fault isolation techniques

#### **1.2.3.5.4 Real-time Software Components for Space Control (7.0 ECTS), Dr. Z. Hanzalek**

The aim of this module is to provide basic building blocks for the computer use in the area of embedded systems for time critical, autonomous, robust applications used in space. The focus is on up to date technologies based on reliable processors and real-time operating systems. After completion a student should know about:

- Introduction to computer aided real-time measurement and control.
- Peculiarities of real-time computer systems for space control.
- Basic structures of RTOS - scheduler, inter-task communication primitives.
- Structure of RTOS VxWorks from WindRiver Systems, development environment Tornado II
- Students will solve several simple tasks in order to get basic knowledge about RTOS VxWorks.

#### **1.2.3.5.5 Distributed Embedded Systems (7.0 ECTS), Dr. Z. Hanzalek**

The goal of this subject is to give students basic knowledge in the area of distributed applications integrated within the controlled technology. The subject ranges from fieldbus systems over synthesis of parallel algorithms to the analysis of distributed applications. After completion a student should know about:

- Basic features of distributed applications (ISO/OSI layers, .....).
- Communication networks used inside space transport machines - fieldbus systems.
- Parallel machine scheduling and synthesis of parallel algorithms.
- Communication protocol analysis by Petri Nets.
- Analysis of distributed applications based on RTOS and RT communication networks.

#### **1.2.3.5.6 Hardware Support in Space Engineering (7.0 ECTS), Prof. A. Střibrský**

To provide an overview of DC, low-frequency and power electronic hardware support for cryogenic and high temperature environment. On completion of this modul, the student should be familiar with:

- characterization of active (semiconductor) and passive parts for extreme temperature
- environment and new materials/technologies improving reliability and lifetime, increasing
- energy density and efficiency, and reducing system size, weight, complexity and launch cost
- low temperature analog circuits design and characterization and analog signal processing
- digital circuits design and characterization, and reconfigurable electronic architectures and
- high-efficient hybrid electronics
- power electronic components usage for high-efficiency high-density cryogenic and high
- temperature instrumentation
- high-efficiency power systems (DC/DC converters, DC/AC converters, power amplifiers)
- power sources for spacecrafts, load versus source management
- extreme temperature reliability of electronic parts/assemblies for space applications and
- their EMC and radiation/climate resistance

#### **1.2.3.5.7 Team Design Project (10.0 ECTS), Prof. J. Bilek, Dr. Z. Hanzalek**

The team design project enables students to get skills in technical practice and cooperation between colleagues. Main topics are interdisciplinary and there are very good preparation for Master Theses planning. On completion the team project a student should

- understand the solving more complicated projects,
- cooperate in group of co-workers
- understand the theory and practice integration
- effectively solved interdisciplinary tasks

#### **1.2.3.6 Science Track 1, 30 ECTS, at UPS, France – Astrophysics, Space Sciences, Planetologi, Research oriented**

**Professor Sylvie Vauclair and collaborators are responsible of all the subjects and modules of this track.** She will be helped by the responsible of the main modules of this master. These responsible are G. Soucail, F. Paletou, B. Escudier and Peter von Ballmoos. They will help her to manage the teaching staff of every subject and module of this track.

The modules will be:

1. Astrophysics
2. Planetology
3. Space Technique
4. Instrumentation

#### Module Descriptions

The students have to follow specific courses during the first semester (30 ECTS altogether), and they have to do a thesis in a laboratory during the second semester (30 ECTS) to obtain their master degree.

##### **1.2.3.6.1 Compulsory subjects: (17 ECTS)**

- Numerical method's and introduction to the celestial coordinates
- Radiative processes and radiative transfer
- Astrophysical and geophysical plasmas
- Formation of planetary systems
- Internal structure of stars and giant planets
- Signal and image processing
- Instrumentation
- Methods of space exploration and observation

##### **1.2.3.6.2 Astrophysics (13 ECTS) - Optional subject**

- Stellar hydrodynamics and transport processes
- General Relativity
- Physics of the Galaxy and the Interstellar medium
- Stellar physics : evolution, atmospheres, magnetism, compact stars
- Extragalactic universe and cosmology

##### **1.2.3.6.3 Space sciences (13 ECTS) - Optional subject**

- Physics of space environment
- Space mechanics and dynamics
- Spatial systems and risk mastering
- Optimal commands and propulsion technics

##### **1.2.3.6.4 Planetology (13 ECTS) - Optional subject**

- Physics of fluids, internal motions, chemical reservoirs
- Laboratory technics , in-situ analyses
- formation and evolution of planetary surfaces
- Planetary atmospheres , physics and environment of giant planets
- Heliosphere, magnetosphere, Sun and solar wind
- Exobiology

##### ***1.2.3.7 Science Track 2, 30 ECTS at UPS, France – Space Technique and Instrumentation, Professional oriented***

Dr. Christophe Peymirat and collaborators are responsible of all the subjects and modules of this track. He will be helped by the responsible of the main modules of this master. These responsible are R. Talon, G. Flouzat, H. Reme, J. Martinez-Vega, G. Skinner, A. Lopez, A. Capdevila and M. Bonnis Sassi. They will help him to manage

the teaching staff of every subject and module of this track. The teaching staff will include 50% of teacher-cum-researcher and 50% of professionals of the industry. Professionals of the industry belong mainly to the industries CNES (Centre National des Etudes Spatiales) and ALCATEL SPACE.

- Spatial Technique
- Instrumentation

Module Descriptions

#### 1.2.3.7.1 Technology and systems (7 ECTS)

The course deals with the spatial systems, spatial technology, spatial mechanics, dynamics and attitude command, and the spatial environment of the Earth. Course content:

- *Introduction to the spatial systems. Spatial technology:* Spatial missions. Spatial system. Spatial vehicles. Earth segment. Mechanics, thermodynamics, electrical, computer architectures. Propulsion
- *Spatial mechanics, dynamics and attitude command:* Spatial system. Keplerian motion. Earth satellites. Orbits. Perturbation theory. Effects of frictions, of the earth flatness. Interplanetary trajectories. Attitude perturbations. Stabilization
- *Spatial environment of the Earth:* Sun-Earth relations : the sun, the interplanetary medium. Ionized environment of the Earth : magnetosphere, plasma, radiation belts. Vacuum and cryogeny : physics of the gas, thermodynamic exchange, application to the spatial conditions. Heavy ions. Orbital remains.

#### 1.2.3.7.2 Technology for missions (11 ECTS)

The course deals with the spatial telecommunication, navigation, Earth observation, Universe sciences and development organisation. Course contents:

- **Spatial telecommunication, navigation:** System architecture. Orbits. Regulation rules. Economic aspects. Satellite liaison. Transmission technics. Scientific payload. Multiple acces. Earth station and equipments. Satellites localisation. Satellite navigation systems. GPS, GLONASS, ARGOS-SARSAT systems. DORIS accurate localisation system. Global Navigation Satellite System II. GALILEO program.
- **Earth observation:** Earth observation objectives : Global environment : atmospheres, ocean, continental surfaces. Territories metrology : natural mediums, anthropised mediums, information systems. Methods and observation tools : Physics of the measure. Captors in optics, close infra-red, micro-waves. Thermal captors.
- **Universe sciences:** Earth environment and interplanetary medium: Detectors, Spectral and temporal analysis. Charged particles, waves, magnetic field. Satellites. Infra-red, sub-millimetric, X and Gamma astronomy: Clouds, stars, interstellar medium, neutron stars, black holes, galaxies. Detectors. Vehicles
- **Development organisation:** Client and sub-contracting. Projects gestion. Product assurance and development.

#### 1.2.3.7.3 Practical lectures (12 ECTS)

The module corresponds to the practical use of the instrumentation related to the spatial industry. Course content:

- **Measurements:** Vacuum and cryogeny : Vacuum. Pumps. Ultra vacuum. Low pressure metrology. Characteristics of a vacuum circuit, conductances, steady and temporary regimes, elements coupling. Liquefactors. Containers
- **Simulations :** Mechanics, thermodynamics, electromagnetic models of a structure: Mechanics model of a structure : Sinusoidal, random and acoustics vibrations. Shocks. Thermal model of a structure : Conduction, convection, radiation. Thermal equilibrium. Temporary and periodical regime. Electromagnetic model of a structure: Electromagnetism compatibility. Conduction, radiation. Sources, receivers, coupling paths
- **Spatial data treatment:** Applications to the Earth observation images and generalization

#### 1.2.3.8 Science Track 3, 30 ECTS at LTU, Sweden – Atmospheric and Space Physics

The modules will be:

- Atmospheric Physics, Professor Sheila Kirkwood + collaborators
- Space Plasma Physics, Associate Professor Carol Norberg
- Solar Physics, Dr. Martin Bohm
- Numerical methods in Space Physics, Associate Professor Mats Holmström
- Solar System Physics, Professor Rickard Lundin + collaborators

## Module Descriptions

### **1.2.3.8.1 Atmospheric Physics; Professor Sheila Kirkwood (IRF)**

The aim of the course is to provide an understanding of the physical behavior of the atmosphere. Course contents: Atmospheric composition and structure. Radiation, temperature and stability. Water and clouds. Earth's rotation and the global circulation. Gravity waves, planetary waves and tides. Thunderstorms and the global electric circuit. Ozone depletion and other atmospheric pollution effects. Climate change - natural and anthropogenic factors. The atmospheres of other planets. The teaching is a combination of lectures and laboratory exercises.

### **1.2.3.8.2 Space Plasma Physics; Associate Professor Carol Norberg**

The aim of the course is to deepen the student's understanding of the plasma physics relevant to the magnetosphere and solar system. The contents of the course: Collisionless shocks, plasma instabilities, the magnetohydrodynamics of the Sun, solar wind interactions with magnetised and non-magnetised planets, magnetospheric physics of the planets in the solar system, auroral physics, magnetospheric storms and substorms. The teaching is a combination of lectures, exercise classes and laboratory exercises.

### **1.2.3.8.3 Solar Physics; Dr. Martin Bohm**

The aim of the course is to give a basic knowledge of solar physics and deeper knowledge in certain areas including a glimpse of current research in the field. The Sun and its activity. The basics of solar physics. The quiet Sun, its interior and atmosphere. The active Sun, helioseismology, explosions on the Sun, active regions. The solar cycle. The hot corona and the solar wind. The heliosphere. Highlights in modern solar research.

### **1.2.3.8.4 Numerical Methods in Space Physics; Associate Professor Mats Holmström (IRF)**

Description: The course will give an introduction to numerical methods used in space physics. The students will learn how to solve mathematical problems encountered in space physics using computers. The contents of the course: Basics of scientific computing, numerical methods for solving mathematical problems that frequently arises in physics, such as ordinary and partial differential equations, an overview of common computational problems in space physics, such as the interaction between the solar wind and planets, and exospheric simulations, and the different methods used to solve these problems, such as fluid, particle and hybrid methods, an important part of the course is assignments, where the students will solve computational problems arising in space physics using a suitable programming languages such as Matlab.

### **1.2.3.8.5 Solar System Physics; Professor Rickard Lundin (IRF)**

Description: The aim of the course is to deepen the student's understanding of the solar system. The contents of the course: Fundamental forces, a tour of the solar system, interstellar and galactic forcing, the sun, the planets, interplanetary space, cosmogony – formation and evolution of the planetary system, exoplanetary systems, solar system space research.

## **1.2.4 Fourth Semester**

### **1.2.4.1 Introduction**

The students will do their Master Thesis work valued at a minimum of 30 ECTS during the Fourth Semester.

The European students from CU, CTU, HUT, and UPS will do their Thesis work at their Home University or at Industry or a research institution with close relations to the home university.

Some of the LTU/Kiruna students and the JMUW students will not do their Thesis at their Home University. They will spend the Second year at a Host university depending on choice of Track.

The Third country students will disperse to different Partner universities, dependent on the subject of their research thesis work.

#### **1.2.4.2 Thesis Work**

The Thesis work in France can be performed in Toulouse which benefits from a large support in industry and research institutions. For instance applied thesis could be realised in industries like ALCATEL SPACE or CNES (Centre National des Etudes Spatiales). Research thesis could be realised in the laboratories belonging to Observatoire Midi Pyrénées.

Thesis work at CU can be undertaken on campus, in association with UK space industry (Astrium, Vega), at the RAL laboratory of the research councils or in collaboration with the Open University.

The Thesis work at CTU, HUT and JMUW can be performed around the laboratories at the universities and/or in space related research projects with connection to the universities.

The Thesis work at LTU will be performed around the excellent facilities in the Esrange base in Lapland area, Kiruna, in close collaboration with the European Space Agency ESA and other Space Agencies around the Globe. Some Thesis work will also be done at NEAT- the North European Test Range at Vidsele.

Some of the Thesis work will be integrated projects in tele-robotics, remote operation, sensor data fusion and automatic control where the participating students are located all around Europe.

#### **1.2.4.3 Thesis Assessment**

The individual research thesis will be assessed jointly by the student's Host University for the research and by the Home University. In cases where these universities are the same, either JMUW or LTU will provide a second assessor.

### **1.3 List of Partner Institutions and awarded Degrees**

| Name of Institution | Title of degree awarded for this Master Course by this institution   | Type of degree awarded |
|---------------------|--|------------------------|
| CU, UK              | MSc in Astronautics and Space Engineering  | Double                 |
| CTU, Czech Republic | MSc in Electrical Engineering and Informatics  | Double                 |
| HUT, Finland        | MSc (Technology)   | Double                 |
| JMUW, Germany       | Diploma Course in Technical Computer Science<br>or<br>Diploma Course in Physics  | Double                 |
| LTU, Sweden         | MSc in Space Technology  | Double                 |
| UPS, France         | Master Professionnel Techniques Spatiales et Instrumentation<br>or<br>Master Recherche Astrophysique, Sciences de l'Espace, Planétologie | Double                 |

### **1.4 Policy and Legal Procedures**

The SpaceMaster Course is based on joint curriculum design, which forms a basis for the recognition of the Course as a whole. Recognition of the Master Course in each participating university is carried out by institutional official procedures, which is to assure also that double degrees (two national M.Sc degrees) can be awarded. The Consortium will set up an Examination Committee, which meets regularly to discuss and follow-up on the procedures and rules related to the SpaceMaster Course.

At the time of the deadline October 31, all the details of legal approval procedures within the Consortium are not finalised. An agreement about all legal approval procedures is planned to be signed by all the partner universities before mid December 2004.

### **1.5 Diploma Supplement**

The Consortium will join an Erasmus Mundus Diploma Supplement to the students final Degrees providing a full description of the curriculum and the role of the universities in the Consortium.

### **1.6 Master Course Status**

The Consortium was created in late June 2004 by an initiative from Luleå University of Technology. There have been long lasting relations between many of the universities before. LTU have had links with CU, UPS and HUT during many years. HUT have had links since many years with both JMUW and CTU – one example is the PELOTE Consortium. Now these groups have joined together in this challenging mission to offer a high quality European SpaceMaster. The Consortium was formally created during its first meeting, July 5 and 6, 2004 in Luleå.

## **1.7 Admission, Selection and Examination criteria**

### **1.7.1 Introduction**

The admission requirements for European and third country students are a good quality Bachelor's degree in Engineering, Natural Science, Mathematics or equivalent qualifications. The third country students apply to the Consortium. The Admission Committee takes the decisions about enrolments and will finalise the list and the reserve list to the Commission before the deadline.

The European students apply at their home university. They have a background from different Courses.

Students from non-English speaking countries are required to have passed TOEFL, IELTS test or equivalent tests with specified results.

### **1.7.2 Admission Criteria**

A good quality Bachelor's degree in Engineering, Natural Science, Mathematics or equivalent qualifications. Admission on competitive basis; the students are assessed on the basis of their previous academic record. Knowledge of English. Students from non-English speaking countries are required to have passed one of the following tests: TOEFL (score 580/237 or higher) or IELTS (score 6,5 or higher) or some equivalent test.

Letter of motivation

A Curriculum Vitae.

Certificates and diplomas from previous university studies.

Transcripts of records including grades and course syllabus from previous university studies. The purpose is to enable the Consortium Admission Board to assess content and level of your studies.

Certificates of relevant work experience and other professional certificates, if any.

### **1.7.3 Application Procedure**

The deadline for applications for Third country students is March 1st .The European students follow the local routines for enrolment at respective partner university.

Required documents:

- Official transcript of the university records and the official Bachelor degree certificate. All documents must be officially true attested copies. All translations must be officially certified and accompanied by the copy of the original.
- Language test report.
- Letter of motivation
- A Curriculum Vitae.
- A copy of the passport.
- Name, address and kind of relation to nearest relative.

Third country students send their Applications to:

Luleå University of Technology

Admission Office

SpaceMaster

971 87 Luleå

Sweden

The documents requested must be in English. The LTU Office for Enrolment will check all the applications.

European students send their Applications to the administration at their home universities and follow the enrolment routines at each partner university.

#### **1.7.4 Selection Process**

The selection process will be carried out by the Admission Board of the consortium. The Board includes professors in charge of the Master Course at each institution of the consortium representative from each partner university. The Chairman of the Admission Board is the coordinator of the program. The Admission Board will meet in the middle of March to do the selection of third-country students. 19 students are proposed for acceptance and 19 students are put on a reserve list. There may also be a list for Asian students.

The students are selected straight to the option and the candidates are asked to indicate three study options when applying. The candidate can be asked to change the option within the program.

The European students follow the admission routines at each partner university.

The selection criteria are the same for third-country students and EU- students. No special conditions apply to third-country students, except for the tuition fees. (question 2.13)

#### **1.7.5 Tuition Fees**

The universities in the consortium will charge tuition fees according to their own national legislation.

### **1.8 Mobility Arrangements**

All the students in the SpaceMaster will study core modules at JMUW, Germany, during the First Semester from early October to mid January. After that they will move to LTU, Sweden at the Kiruna Space Campus starting the Second Semester in February 1 and continue studying core subjects until early June.

During the Second year the European students from CU, CTU, HUT and UPS will study at their home universities. The LTU- and JMUW-students will be spread out between all the partner universities depending on their specialisation. The third country students will be spread out about equally between the partner universities.

### **1.9 Application and Selection Process for Third Country Students**

The selection criteria are the same for third-country students and European students. No special conditions apply to third-country students, except for tuition fees when applicable. (See 2.10)

### **1.10 Distribution of third country students within the Consortium**

The distribution of students is a part of the selection procedure. A third-country student can apply for one of the options of the SpaceMaster and in addition be asked to give second and third choice. In principle the students are distributed within the Consortium according to their wishes. However, all partners should receive agreed number of third-country students, and therefore there will be limitations. Third-country students are informed about restricted number of study places in each partner university in admission procedure material.

### **1.11 Service provided to welcome and host them**

#### **1.11.1 Introduction**

All partner universities have an Office for International Affairs and thus ready mechanisms to host third-country students. Staff at these offices will assist the students in housing and other practical matters and provide the students with written "Foreign student guide" in English. All the partner universities are very familiar and experienced in taking care of exchange students and international Master students.

#### **1.11.2 JMUW, Würzburg**

The Office for International Affairs at JMUW, Würzburg will assist the SpaceMaster students to get good accommodation. During the month prior to each semester (i.e. September and March), there are intensive German language courses (5 daily hours, 5 days a week, four weeks) to prepare international student for their studies at Würzburg. During the semester, there are also courses parallel to the actual lectures.

With their Letters of Admission, All international students receive written information on the enrolment procedure and all steps which have to be taken in advance. In addition, a list with the names of the student tutors employed by the International Office is also sent out to all students. This way, international students can get in touch with the tutors from their home country and make the necessary arrangements for their arrival: pick up from the central station, handing over the room key in the dormitory on weekends, orientation in town and at the university. The tutors can act as buddies, and it is therefore easy to make new contacts with the help from someone who is already well acquainted in Würzburg.

At Würzburg, there are special housing arrangements for international students. Exchange students can rent a room in one of the dormitories of the "Studentenwerk Würzburg". The other international students can avoid waiting lists and directly receive a dorm room by buying the "Servicepaket" (service package) from the Studentenwerk. Affordable meals are available through the dining facilities of the Studentenwerk. All students at Würzburg have a semester ticket for free transportation in the city.

The International Office together with the Student Representative Body organises a programme of welcome activities and excursions. These include free tours of the City, the Würzburg Residenz and Fortress Marienberg, special tours of the university library etc. There is also a welcome meeting with the President and the Chancellor of the University of Würzburg and various excursions throughout the semester.

Academic guidance can primarily be sought from the academic counselors in the departments or the "Zentrale Studienberatung" ("general" student advisors); the International Office remains a partner for service and advice throughout students' courses of study.

#### **1.11.3 LTU, Kiruna**

LTU guarantee good student accommodation to all students in the SpaceMaster at the Kiruna Space Campus. The students will be welcomed by students from the Kiruna Space Campus when they arrive to the railway Station / airport. Swedish language courses, Swedish culture and Sámi culture will be offered. The Student Union arrange numerous social activities, such as dinners, parties and trips. Study trips to the iron mine, the famous Ice Hotel at Jukkasjärvi and of course to the Esrange Rocket base will be arranged. There are excellent possibilities for wildlife and winter sport in the Kiruna region.

#### **1.11.4 All Partner universities**

- The International Offices at the other Partner universities will assist the SpaceMaster students to get good accommodation.
- Within the Consortium, special attention is paid to study counselling, which is organised in all partner universities. All participating students will have a tutor (mentor), who is usually a member of staff (for example recently graduated researcher) in the hosting university. The purpose of the tutoring system is to ensure a systematic monitoring of every student's progress and to ensure, that students are made aware individually of their performance frequently. In addition, all students have an opportunity to receive advice on studying from the teachers and planning officers throughout the programme.
- All partner universities will provide courses in the home language for the SpaceMaster students

#### **1.12 Financial management**

The coordinating Institution, Luleå University of Technology, LTU, manages all financial matters through LTU:s central administration. The Deputy Head of Administration at LTU will together with the coordinator of SpaceMaster nominate a financial group that will take care of all financial administration within the Consortium. The financial group will work in close collaboration with the SpaceMaster coordinator and the local coordinators at each partner university

- The universities in the consortium will apply the usual tuition fees of each university when applicable
- LTU will pay the Grants for third country students and scholars in the Master Course through a bank transfer once a month
- LTU will pay the fixed amount of money (5 000 Euro) to the third country students after that the student has arrived to the entrance university- JMUW at Würzburg for the First year. There may be some exceptions to that rule in case a third country student has a need to pay for the ticket before arrival. In that case the Consortium will make sure that the transferred amount of money will pay for the ticket.

#### **1.13 Language policy**

The language of instruction and the language of examinations will be English except at UPS where there will be both French and English. Courses (including course material), examinations, and study counselling are available in English. All universities offer a variety of language courses in addition to English language courses. Students are encouraged to learn basics in other national languages represented in the Consortium (German, French, Swedish, Finnish).

#### **1.14 ECTS, External Body, Quality assurance**

All partners have institutional quality assurance mechanisms in place, of which the most common are student questionnaires and Education committees. Questionnaires typically incorporate areas such as content of the module, the quality of teaching, availability of other guidance and support on the module and module material. In Education committee's quality of modules are frequently discussed. Institutional procedures of each institution are followed.

Within the SpaceMaster Course, the Examination Committee has the overall responsibility of the Master Course. The Examination Committee has a representative from each partner university and meets on a regular basis to discuss about quality issues. The Chairman of the committee is the coordinator of the SpaceMaster.

The overall evaluation of the SpaceMaster Course will be carried out also by external evaluation team involved in the Erasmus Mundus framework. Most of the partners within the consortium use ECTS -based credit systems. In addition, ECTS grading systems can be used by converting local grades to ECTS grades.

#### **1.15 Evaluation and quality assessment mechanism**

The Examination Committee of Masters Consortium monitors the overall quality of the Course on a regular basis. In addition to student questionnaires in each partner university, all students are asked to give feedback on their experiences across the whole Course when graduating. Responses and actions are taken with regard to this feedback.

## **1.16 Co-operation mechanism**

The basis for co-operation within the Masters Consortium is excellent because among several partners, active co-operation has existed on a research level. In educational level, the core of the co-operation is grounded on the Admission committee and Examination committee. The purpose of these committees is to ensure, that admission procedure, regulations, quality of the Course, student counseling and other study related matters are administrated jointly. In addition to formal meetings, the consortium will arrange e-meetings.

## **1.17 Links to Research Activities.**

### **1.17.1 Introduction**

The subject matter of much of the taught material of the Masters already reflects areas of research within the consortium. This research spectrum may be summarised with the following keywords

autonomy    tele-robotics    remote operation    distributed systems    sensor data fusion  
automatic control    multi-body dynamics    flight dynamics & control    data communication

These skills, taught on the SpaceMaster, will be adapted and developed for future needs.

In searching for solutions for future space science, planetary exploration and exploitation of near-space and planetary resources, the synergistic application of such multi-disciplinary technologies will be paramount. Remote operation on locations, which are distant in terms of the communication round trip, means that actions need to be performed with embedded safety systems. Remote vehicles will have opto-electronic and other sensors to survey the local environment. Collaboration between sets will need local autonomy. The Earth-bound operations supervisor will need a simulation of both this environment and also the dynamics of the robot vehicles. This may be termed the remote reality.

The research into such complex systems may be illustrated during project work on the SpaceMaster, where competing teams at different locations remotely and simultaneously direct firstly their own and then each others robot vehicles to perform a defined task. Internet and wireless connections would be used for data and command communications. Some performance criteria would enable a clear winning team to be declared.

The development of such technologies will have wide spin-off into such spheres as

- remote construction in hazardous or inaccessible environments
- remote decontamination in polluted environments
- tele-medicine in remote locations
- intelligent monitoring and alarm systems for the factory and home

### **1.17.2 Example 1**

A very good example of such a link between the research and the planned SpaceMaster is the currently ongoing CubeSat program at the the Bayerische Julius-Maximilians University of Würzburg

(<http://www7.informatik.uni-wuerzburg.de/cubesat/index.html>). Within the scope of this program a whole ready to fly satellite, the UWE-1, is being developed and build. The work (structure, thermal and electrical design, onboard data handling and software, communication data flows and protocols ...) on the satellite is completely done by students in the context of practices, diploma thesis and PHD works. At the current status the structure mass model undergoes vibration and sound tests at a satellite testing facility of the ESA. After successful testing it will be launched in the first quarter of 2005. The scientific task of the satellite in orbit will be the examination of TCP/IP based protocols for space communication and the testing of newly developed solar cells which have been submitted by a project partner. The student which will enroll for the SpaceMaster in the future will participate in follow-on projects in contexts like satellite design and planetary robots design.

### **1.17.3 Example 2**

Another good example of links between education and research are the REXUS and BEXUS projects at the Esrange area in Lapland, Kiruna, where rockets and balloons are launched in close collaboration with the

European Space Agency ESA and other Space Agencies around the Globe. Relatively close to Kiruna is also NEAT- the North European Test Range at Vidsel. Esrange and NEAT will be important resources in the SpaceMaster programme.

### **1.17.4 Example 3**

Toulouse and the Midi-Pyrénées region represent a leading national and international pole in the fields of Astrophysics and Planetology. In particular, the “Laboratoire d’Astrophysique” and the “Centre d’Etude Spatiale des Rayonnements”, laboratories of the “Observatoire Midi-Pyrénées”, perform research activities in numerous fields, from the Solar System to the large scale Universe, from a theoretical, modelling and observational (ground and space observations) point of view. The studied subjects of the track “2.2.3.5 Science Track 1, 30 ECTS, at UPS, France – Astrophysics, Space Sciences, Planetology, Research oriented” represent the complete field of astrophysics, from stellar physics to the cosmology, as well as the planetology. Some of the subjects, like the internal structure of the stars and the giant planets, are treated from a general point of view in these two research fields. Others are more specialized, like the study of the primordial Universe or the study of telluric planets.

### **1.17.5 Example 4**

At Cranfield, in the wider dynamics area, SpaceMaster students will be able to perform their research thesis in areas mapping doctoral and staff research. These include Smooth Particle Hydrocode and Finite Element methods to study hypervelocity and lower velocity impacts, flight control of autonomous aircraft, such as those for flight in the Martian atmosphere and formation flying of spacecraft for distributed systems such as the Darwin antenna. In addition, there are general system interests, such as the integration of Micro System Technology into low cost nano-spacecraft, air vehicles for Mars surface landing, the application of SAR interferometry to changes in topography and launch vehicle configuration comparison.

## ***1.18 Distinctive European added Value of the SpaceMaster***

The Consortium is unifying expertise from a broad range of European universities to create a Joint European Master in space science and technology with high quality modules in the space area. The students will experience projects and research activities during work in projects and on the Master Thesis. Many of these projects will take place in close collaboration with the European Space Industry. So the SpaceMaster has a potential to provide Europe’s Space industry and research institutions with high quality engineers and researchers in the space area. The concept of the first year as a common year will create tight and long-lasting links and friendship between the European students and the third country students – hopefully they will continue to collaborate in their future profession.

Furthermore, the students in the SpaceMaster will experience many different European climate, nature and culture: German, Scandinavian, French, Czech and English. This will help to go beyond the differences between different countries of Europe. This point is important because scientific projects require more and more expensive equipments to increase the knowledge of our planet and the universe surrounding it. These equipments cannot be usually funded by one country and requires a strong collaboration between the scientific organisms of each country. Such a collaboration cannot take place in the absence of a strong knowledge of the culture of the involved countries and strong links between European scientists.

Finally, the inclusion of third countries students will help to create links between Europe and Third Countries. The students of those countries will acquire the knowledge of European technologies that they will import in their country when they will come back home. Such a transfer of technology will be facilitated if one works together on common scientific projects.

We hope that the master we propose will be the beginning of a move towards the creation of European scientific projects and a collaboration with Third Countries that will be beneficial to Europe in the long term.

## ***1.19 Describe any aspects of the Master Course which offers potential examples of good practice which could be disseminated more widely***

We regard that the structure of the SpaceMaster:

- A common first year at two partner universities

- A good variety of specialisations Tracks with close links to research activities and industrial projects during the Second year
- A good diversity of European top class universities
- A good organisation to take care of and mentor the third country students and offer them activities to experience different European Culture

could serve as a model for future European Master Courses.

### ***1.20 Other aspects***